SP-F9 Evaluation of the Feather River Hatchery Effects on Naturally Spawning Salmonids

October 25, 2002

1.0 Introduction/Background

The California Department of Water Resources (DWR) constructed the Feather River Hatchery (FRH) to mitigate for salmonid spawning habitat lost due to the construction and operation of Oroville Dam/Reservoir complex. Since the late 1960s, the FRH, operated by the California Department of Fish and Game (CDFG), has released millions of spring and fall Chinook salmon fry, fingerlings, smolts and yearlings, and yearling steelhead to fulfill DWR's Oroville Federal Energy Regulatory Commission (FERC) license mitigation responsibility. The FRH releases provide significant contributions to ocean commercial and recreational fisheries (Chinook salmon) and inland recreational fishery (Chinook salmon and steelhead) (Dettman and Kelley 1987 and Cramer 1992).

These terms will be used in the study plan:

- Chinook salmon – all races of the species Oncorhynchus tshawytscha.
- Steelhead – a race of the species Oncorhynchus mykiss. Steelhead is listed as threatened pursuant to the federal Endangered Species Act (ESA).
- Spring Chinook – a race of Chinook salmon that typically enters freshwater in the spring and holds in the rivers until spawning in the early fall. This race or run typically spawned in the higher elevations of the Sierra Nevada. In this report, the term spring Chinook is used for those salmon that enter the Feather River in May and June as bright fish and spawn in the September/early October period. There was a native spring run in the Feather River. Spring Chinook is listed as threatened pursuant to the federal and state endangered species acts.
- Fall Chinook – a race that enters the rivers in the early fall and typically spawns within a few days or weeks. In this report, the term fall Chinook is used for those fish that enter the river beginning in August and spawn in the September through December period, with peak spawning generally in October through early November. There was a native fall run in the Feather River. Fall Chinook is a candidate species pursuant to the federal ESA.
- Late fall Chinook - a race behaviorally similar to the fall run except it spawns somewhat later in the year and generally at a larger size. Juveniles leave their natal streams in the late fall early winter period. There does not appear to be a significant late fall run on the Feather River now or in the past (Yoshiyama et al.2001) with the present late fall run most abundant in the Sacramento River between Red Bluff and Keswick Dam. (Note: In 1970 DFG attempted to introduce a late fall run in the Feather River by planting over one million eyed eggs from the Coleman National Fish Hatchery. The FRH hatchery received late fall adults for a couple of generations but the run failed to persist – DFG 1974.) Late fall Chinook is a candidate species pursuant to the federal ESA.
- Winter Chinook – a race that enters freshwater in the late winter/early spring and spawns in the late spring through mid-summer. The winter run is now restricted to the Sacramento River

between Keswick Dam and Red Bluff, although a few winter run enter Battle Creek. Winter Chinook is an endangered species under both the state and federal endangered species acts.

- Naturally spawning salmonids – refers to all anadromous salmonids that spawn in streams. Naturally spawning salmonids differ from wild salmonids in that there may be a significant fraction of the spawning population that is of direct hatchery origin.
- Phenotype – characteristics of a run based on run timing, size, in-stream holding times, timing of emigration, etc.
- Genotype – characteristics of a run based on genetic composition of individual members of the population.
- Inbreeding depression. A decline in reproductive fitness associated with mating of restricted numbers of individuals from a normally outbreeding population.
- Outbreeding depression. A decrease in reproductive fitness caused by crosses between normally reproductively isolated breeding populations.
- Straying - Adult salmon generally return to the stream in which they were hatched. Fish that do not return to natal streams are called strays. Straying is a natural component of all wild anadromous salmonids but the straying rate may be increased by such hatchery related measures as off site planting and planting juveniles at times outside their normal migratory period (e.g. - planting yearlings when most of the stream fish emigrate as smolts).

As defined in this study plan the Feather River Hatchery includes the fish barrier dam below Oroville Dam, the fish ladder, holding tanks, hatchery buildings and raceways. A separate fish rearing facility, the Salmon Stamp funded Thermalito complex, is also included in this evaluation because Chinook salmon reared in this enhancement program are derived from gametes taken at the main hatchery and production is mixed with that from the main hatchery for release into San Pablo Bay. Hatchery activities included in this study plan include spawner selection, egg take and fertilization, incubation, rearing practices (including disease control) and release strategies, including release site. This evaluation includes an analysis of planting hatchery- reared salmonids in Oroville Reservoir as part of a FERC mandated program to support a reservoir coldwater fishery.

The FRH is one of five major Central Valley hatcheries producing and releasing fall Chinook (FRH, Coleman National Fish Hatchery, Nimbus Fish Hatchery, Mokelumne Fish Hatchery, Merced River Fish Facility); one of three producing and releasing steelhead rainbow trout (CNFH, Nimbus and FRH); and the only hatchery producing and releasing spring Chinook. The Coleman and Livingston Stone national fish hatcheries respectively produce and release late fall and winter Chinook. An examination of the effects of FRH operations and facilities must consider any impacts in the context of the past and present practices of the entire Central Valley complex of hatcheries. Waples (1999), in a paper on myths about hatcheries, emphasized that examination of hatchery impacts should look at hatchery programs in the context of fish culture and fisheries management, not the hatcheries per se. For example, if fish culture practices call for exchange of genetic material between different drainages (either by transfers from hatchery to hatchery or by planting programs), these practices must be considered when evaluating the impacts of individual hatcheries.

Although there may be few late fall Chinook strays from the Coleman National Fish Hatchery in the Feather River (A. Kastner, DFG personal communication) this study focuses on fall and spring Chinook and steelhead. In spite of this focus the plan will address any impacts of hatchery operation on late fall, and winter Chinook, that may stray into the Feather River

The study plan focuses on several potential impacts of hatchery operation on naturally spawning salmonids. These potential impacts include (adapted from NRC, 1966):

- Effects on harvest – both commercial and recreational fisheries for Chinook salmon and recreational for steelhead. A concern is that production from the FRH and other hatcheries has lead to the mixed stock fisheries that can overfish depleted natural stocks.
- Genetic effects – Hatchery operations can potentially cause problems with inbreeding and outbreeding depression and loss of genetic diversity within and among stocks.
- Domestication – Hatchery practices can lead to genetic adaptation to the hatchery, an adaptation that can reduce overall population fitness.

Campton (1995) further categorized the potential genetic effects of hatchery production as:

- Direct genetic effects of hatchery operation and artificial propagation on hatchery fish – for example, loss of within-population genetic diversity and domestication.
- Direct genetic effects caused by natural spawning and interbreeding of hatchery and natural populations – for example outbreeding depression.
- Indirect effects on natural stocks due to competition, predation and disease transfer.

Hatchery operation can have benefits – eg improved ocean and inland fisheries. The final evaluation will also identify any economic benefits.

The general approach to the study involves completing several tasks involving:

1 Describing the goals of the Feather River Hatchery, and how these goals have changed over time;
2 Reviewing and summarizing the literature regarding the impacts of salmonid hatchery operations on naturally spawning salmonid populations;
3 Examining the past and present hatchery practices in the FRH and other Central Valley hatcheries
4 Documenting the results of genetic analyses of Chinook salmon and steelhead from the FRH and other Central Valley streams and hatcheries;
5 Analyzing the results of tagging/marking studies to estimate the contribution of FRH nominal fall and spring Chinook production to ocean and recreational fisheries, escapement and to straying
6 Using information from other study elements examine the impacts of the hatchery on in-river water quality and disease transmission
7 For steelhead in particular, evaluating in-stream rearing, and possible competition, between hatchery produced and naturally produced fish.
8 Examining potential changes in hatchery practices, such as releasing spring run juveniles directly in the Feather River that may reduce any observed impacts.

The information derived from these, and from other study elements in the FERC process will be organized into a final comprehensive evaluation of the benefits and concerns about hatchery operations.

Hatchery evaluations as part of the FERC process will be coordinated with take and other hatchery operations issues as part of DWR and CDFG obligations pursuant to provisions of the federal ESA.

The following provides a brief background on the mitigation goals of the FRH and some of the complications expected to be addressed in the hatchery evaluation process.

The actual mitigation goals for the FRH are defined in terms of the numbers of eggs taken each year for rearing and the numbers of fish to be released as smolts or yearlings. CDFG (1999) has the following goals by race or species:

For Mitigation

Race or species	number of eggs to be taken	number and stage at release
Spring Chinook	up to 7,000,000	5,000,000 smolts
Fall Chinook	up to 12,000,000	6,000,000 smolts
Steelhead	up to 1,000,000	400,000 yearlings

For Ocean Enhancement – Salmon Stamp facilities at Oroville

Fall Chinook	from egg take above	2,000,000 smolts

For Ocean Enhancement – Salmon Stamp facilities on the Mokelumne River

Fall Chinook	up to 4,000,000 eggs from above fall Chinook egg take

Chinook salmon and steelhead eggs, adults, and juveniles from the FRH have been used at other hatcheries (Coleman National Fish Hatchery, Nimbus Hatchery on the American River and the Mokelumne River Hatchery) when spawning escapement to those hatcheries, or other conditions, limited their production. In addition, for more than three decades researchers have used tagged and externally marked juveniles from the FRH to help address such important fish management questions as: (1) the rate at which juvenile salmon enter water diversions; (2) the importance of the Yolo Bypass to salmon production and; (3) the survival of juvenile Chinook salmon through the Sacramento-San Joaquin Delta. This use of eggs and juveniles complicates the hatchery evaluation by adding additional release points (with increased straying potential) for FRH produced fish.

Evaluation of the FRH as a DWR mitigation facility is also complicated somewhat by some non-mitigation aspects of the take and rearing of eggs from mature Feather River Chinook salmon. With support from California's Salmon Stamp Program, Chinook salmon embryos from the FRH are used at the Thermalito Annex to rear and release juveniles beyond DWR's mitigation responsibilities (so-called "enhancement production"). Eyed eggs from the FRH have been taken to CDFG's Mokelumne Fish Hatchery for rearing in a similar Salmon Stamp supported enhancement program. (In recent years escapement to the Mokelumne River has been adequate to satisfy mitigation and enhancement needs and there have been no egg transfers from the FRH.) Juvenile Chinook salmon from the Feather River have also been used to stock inland reservoirs (including Lake Oroville and Lake Almanor above the hatchery) to provide cold-water sports fishing opportunities.

For purposes of the FERC process, the hatchery evaluation is limited to the mitigation aspects of the FRH, including the FERC required planting of juvenile Chinook salmon in Oroville Reservoir. In reality, the evaluation will include all aspects of the hatchery operation and the mitigation portions subsequently sorted out. For example, mitigation and enhancement juveniles are routinely moved between the FRH to the Thermalito facilities for disease control and other purposes and the enhancement and mitigation production are mixed for transport to San Pablo Bay. Some juvenile Chinook salmon planted in Oroville Reservoir have escaped the reservoir, moved to the ocean and have returned as adults (Eric See, personal communication).

A final complication in analyzing the impacts of the hatchery involves changing hatchery practices over the past three plus decades. For example into the nineties, planting surplus fry in many Central Valley streams was a common hatchery practice. (The 1999 hatchery operations plan, CDFG 1999, stipulates that this practice is no longer allowed.) At various times FRH Chinook salmon have been planted in the Feather River as fry, fingerlings, smolts and yearlings. Since the mid-80s most of the production has been planted as smolts in San Pablo Bay. Also the length of time it takes to plant production Chinook has changed from April through September to April through July – mainly due to the use of larger capacity transport vehicles.

In a recent report, the National Marine Fisheries Service (NMFS) and CDFG (NMFS and CDFG 2001) reviewed practices in Central Valley hatcheries operated by CDFG, including the FRH. The report identified three principal hazards of hatchery operations to listed winter and spring Chinook and steelhead:

- Genetic hazards caused by reducing genetic diversity in depressed natural populations;
- Ecological hazards to natural populations caused by straying, including competition for spawning sites and disease transmission; and
- Management hazards caused by the inability to differentiate hatchery from wild stocks. (This inability could be masking declining productivity of natural populations.)

The NMFS/DFG report further cautioned that managers should be concerned about management and genetic hazards because they have high risks of occurrence. The hazards are particularly troublesome because they include the risk of extirpation of natural stocks. Several times in the main report and in an appendix (Appendix 1 "Off-site Release and Straying Subcommittee Report") the authors referred to straying as a "significant problem" and mentioned the present practice of releasing production in San Pablo Bay as a particular concern. The report included a recommendation to tag (and fin clip) and release all FRH spring production in the Feather River and consider the same release strategy for fall run production.

NMFS and CDFG recommended that all Central Valley hatcheries prepare Hatchery and Genetics Management Plans (HGMPs) to minimize the risks to threatened and endangered salmonids. NMFS (1999) developed a detailed format for the HGMP, intended to provide a single comprehensive source of hatchery information for planning and to satisfy permitting requirements under the federal Endangered Species Act (ESA). In a recent evaluation of the Coleman National Fish Hatchery (CNFH) and the Livingston Stone National Fish Hatchery (LSNFH), the U.S. Fish and Wildlife Service (USFWS) used the HGMP template for their biological assessment (USFWS 2001).

This NMFS/DFG report will be particularly important in the analysis of hatchery impacts in that an interagency team is being assembled to continue to review DFG's salmonid hatcheries and to propose changes to hatchery operations that minimize risks to naturally spawning salmonids and their support ecosystem (Chuck Knutson, DFG, personal communication). This study plan and resulting documents should provide information needed in DFG/NMFS efforts to address similar hatchery-related issues. It is likely that much of the information developed in this FERC-related effort will be incorporated into a HGMP.

With respect to the effects of hatchery operations, steelhead present a much different case than Chinook salmon. This special case is because:

- Relative to Chinook salmon, the FRH produces few juvenile steelhead.
- All juvenile steelhead production is released as yearlings in the Feather River.
- For the past few years all juvenile steelhead produced in Central Valley hatcheries must have external marks (adipose fin clips) to distinguish them from wild fish. In addition FRH production has been coded wire tagged. (Beginning in 2002 FRH steelhead will be fin clipped but will not be tagged.)
- Juvenile steelhead may spend one or two years in freshwater before migrating to the ocean, and in some cases may not migrate at all. Steelhead emigrants are relatively large compared to emigrating Chinook salmon – 150 - 200 mm total length for steelhead compared to 40 – 120 mm for fall and spring Chinook salmon.
- In contrast to Chinook salmon some steelhead survive spawning and may return to the ocean and spawn again in subsequent years. (All steelhead surviving the spawning process in the FRH are returned to the Feather River.)
- There is no commercial fishery for steelhead and the freshwater anglers are only allowed to keep hatchery (adipose clipped) fish. In addition, it appears that significant numbers of immature fish ("half pounders", ie immature steelhead that are 12-15 inches long) are taken in freshwater – many in the Feather River.

As summarized by McEwan (2001) the complex life history (including sampling difficulty) and the lack of commercial importance have resulted in comparatively little information about Central Valley steelhead. The documentation leading to listing the Central Valley steelhead Evolutionary Significant Unit (NMFS 1996 and 1997, and Busby and others 1996) resulted in the compilation of much of the available information on west coast steelhead – compilations that will be an important information source for the hatchery evaluation. For example, Busby and others used allozyme analyses to demonstrate that the genetic structure of steelhead from the Coleman National Fish Hatchery, the FRH and wild fish from Mill and Deer creeks and the Stanislaus River was similar and did not resemble the genetic structure of coastal populations. On the other hand, the genetic structure of steelhead from the Nimbus Hatchery and the American River resembled that of their founding stock from the Eel River.

2.0 Study Objectives

The objectives of this study are to:

- Confirm and clearly define the mitigation goals and objectives of the FRH;
- Characterize the non-genetic attributes of salmonid resources in the Feather River and other Central Valley, including run size, timing, emigration (timing and numbers) and historical abundance and distribution;
- Characterize the Central Valley fish management context in which the FRH operates including other hatcheries, interbasin transfer of genetic material, escapement goals and commercial and recreational fisheries management;
- Provide a comprehensive description of the physical and operation characteristics of the FRH for the 1967-2002 period of operation;
- Characterize the genetic composition of Chinook salmon and steelhead spawning in the Feather River and entering the FRH;
- Characterize the genetic composition of Chinook salmon and steelhead spawning in other Central Valley streams;

- Estimate the hatchery contribution to Feather River in-river and hatchery populations of Chinook salmon and steelhead;
- Estimate the numbers (and rate) of FRH Chinook salmon that stray to other Central Valley streams and hatcheries;
- Estimate the numbers of Chinook salmon from other Central Valley hatcheries that stray into the Feather River;
- Estimate the contribution of the Feather River Hatchery production to commercial and recreational fisheries;
- Assess the ongoing and future impact of the FRH's Oroville mitigation activities on naturally spawning Central Valley salmonid populations;
- As part of the previous objective, specifically assess the likelihood of disease transmission from hatchery releases to wild fish (fish releases below the hatchery) and to hatchery fish (fish released in Oroville Reservoir) and the direct and indirect effects of hatchery operation on water temperatures in the Feather River;
- Construct conceptual models of the role, and impacts of, FRH operation on Chinook salmon and steelhead in the Feather River and in other Central Valley streams;
- Assess the role of the FRH in public education and outreach;
- Assess the economic and other contributions of the FRH to the California economy;
- Develop information to be used in identifying and assessing the feasibility of potential additional protection, mitigation and enhancement measures; and
- To the extent possible identify the effects of possible changes of hatchery operation on Central Valley salmonid populations, the commercial and recreational fisheries, and marine mammals.

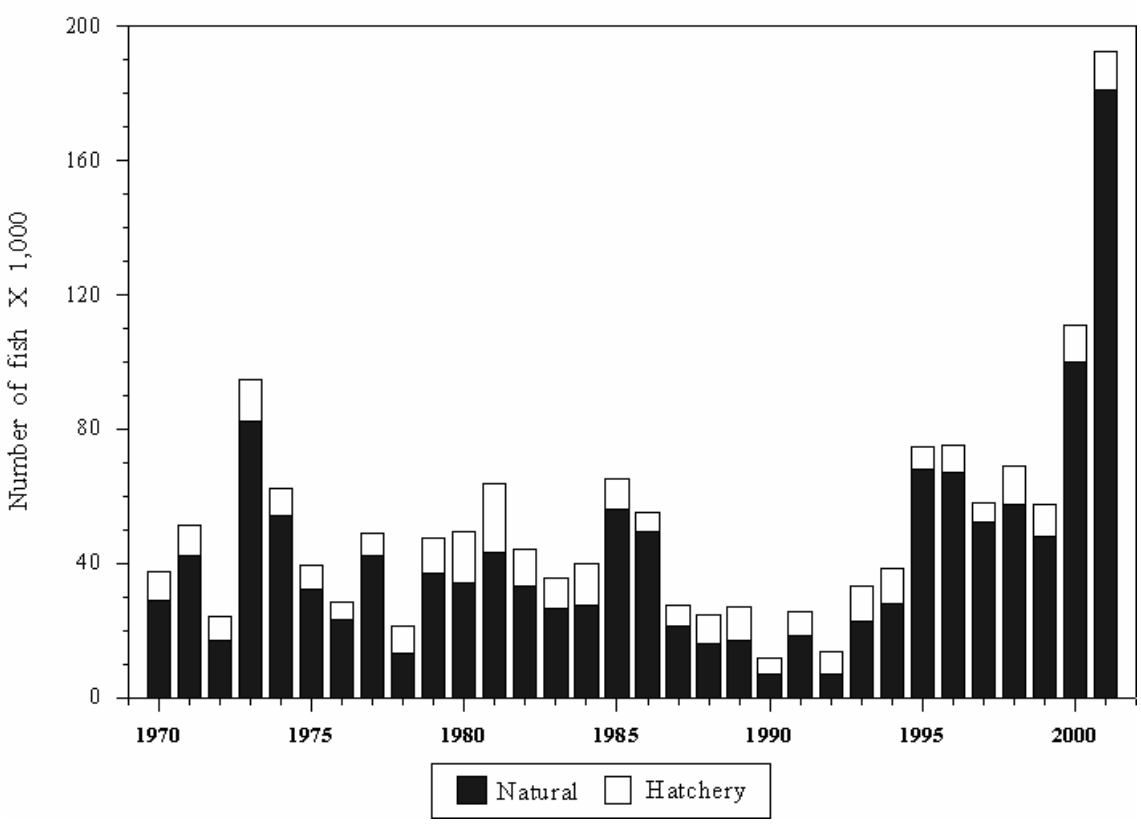

Figure 1. Annual fall-run escapement to the Feather River, natural and hatchery contribution. (Chappell, 2002)

3.0 Relationship to Relicensing/Need for Study

The FRH is an integral component of the Oroville complex, and its operation has the potential to adversely affect naturally spawning salmonid runs in the Feather River and other Central Valley streams. As mentioned previously a 2001 draft report by CDFG and NMFS suggests that the FRH practice of planting hatchery production in San Pablo Bay (instead of in-river) may have caused increased straying. This increased survival and straying may have impacted Chinook salmon and steelhead runs in other streams, in particular those with wild spring run (for example Mill, Deer and Butte creeks). The report also suggested that hatchery practices have co-mingled spring and fall Chinook in the hatchery and impacted the threatened spring run.

On the positive side, the FRH has released millions of juvenile salmon in the past 30 plus years and there are many fall-run Chinook salmon returning to the Feather River each year. These fish appear to have made significant contributions to the ocean and inland commercial and recreational fisheries and escapement to the Feather River. See Figure 1 for recent estimated fall Chinook escapement to the Feather River, including the hatchery. Observations indicate that there is natural steelhead spawning in the Feather River (B.Cavallo, personal communication) but it is not now possible to estimate steelhead escapement. Until the spring Chinook genetic questions are resolved, it is not appropriate to show escapement figures for this race. After almost 30 years of operation, and with new thinking on the roles of hatcheries, it is time to evaluate the hatchery, its mitigation responsibility and operational practices.

Identification and quantification of project effects on fish and fish habitat has been recognized as an issue by relicensing stakeholders including stakeholders with mandatory conditioning authority and is a FERC requirement. Evaluation of project effects on wildlife resources is also required for CEQA/NEPA compliance.

Listings of the spring run as threatened pursuant to the federal and state endangered species acts and steelhead as threatened under the federal Endangered Species Act require that the State obtain take authorization in order to operate the hatchery. Although the fall run is not listed (but is a candidate species) under the federal ESA, there is considerable concern about the effects of hatcheries on naturally spawning fall Chinook runs in the Feather River and other Central Valley streams. As mentioned previously, NMFS will require that hatcheries affecting listed species, such as the FRH, prepare a Hatchery and Genetic Management Plan (HGMP). Information collected and reported in this evaluation can form the basis for the FRH HGMP.

These and other issues about hatchery operation must be addressed in the FERC relicensing process and, in light of the results of this study and analyses, the new FERC license may stipulate changes in hatchery practices.

Section 4.51(f)(3) of 18 CFR requires reporting certain types of information in the FERC application for license of major hydropower projects, including a discussion of fish, wildlife and botanical resources in the vicinity of the project. The discussion needs to identify the potential impacts of the project on these environmental resources, including a description of any anticipated continuing impact for any on-going and future operation. This study fulfills these requirements by evaluating potential project effects on anadromous salmonids and their habitat in Feather River below the Fish Barrier Dam.

4.0 Study Area

This study plan is designed to evaluate the impact, if any of FRH released salmonids on natural spawning salmonids in the Feather River and other Central Valley streams. In addition this study will evaluate whether the FRH has satisfied DWR's mitigation requirements, and supplemented Chinook salmon harvest in the ocean commercial and recreational fisheries. The study area thus includes:

- The hatchery site (including the fish barrier dam and ladder)
- Oroville Reservoir (due to planting Chinook for recreational harvest)
- The Thermalito facilities
- The Feather River from the fish barrier dam to its confluence with the Sacramento River;
- The Sacramento River below Keswick Dam including its significant tributaries – including, but not limited to, Battle Creek, Mill, Deer, Butte and Clear creeks, and the Yuba, Bear and American rivers;
- The San Joaquin River and its significant tributaries including the Stanislaus, Tuolumne and Merced rivers;
- Calaveras and Mokelumne rivers;
- The Sacramento-San Joaquin Delta;
- The San Francisco Bay;
- Other west coast streams as appropriate; and
- The coastal ocean from southern California to British Columbia (the area where Chinook salmon released from the FHR may be harvested in commercial and recreational fisheries).

Study plans approved by the Environmental Work Group define the limits of the study area. If initial study results indicate that the study area should be expanded or contracted, the Environmental Work Group will discuss the basis for change and revise the study area as appropriate.

5.0 General Approach

The general approach to the analysis of the effects of the FRH on naturally spawning salmonids (in the Feather River and other Central Valley streams) involves a combination of literature review, analysis of studies conducted since the early 1990s and new field and laboratory studies as appropriate. In recognition of the uncertainty and complexity of the evaluation process, and the expectation that additional studies will be proposed during literature review and data interpretation, it is likely that studies and analyses will continue past the 2005 deadline for submittal of the relicensing application to FERC. To the extent possible, these studies will be identified in the FERC submittal.

Evaluation of the FRH impacts will be based on review and synthesis of the vast amounts of information collected about the hatchery, the Feather River and other locations in the Central Valley and the Pacific Ocean. Three recent publications provide key contextual information for the analysis of hatchery impacts:

- The biological assessment of the effects of the Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery on salmonids (USFWS 2001);
- The NMFS/DFG review of California's salmonid hatcheries (NMFS/DFG 2001);
- The NMFS guidelines for a Hatchery Genetics Management Plan (NMFS 1999).

Compilation and analysis of existing data will be accompanied by an extensive review and summary of the literature about the impacts of salmonid and other hatcheries on natural spawning fish populations and communities as well as the use of hatcheries as a fish management tool. As stated by Waples (1999) " Hatcheries are intrinsically neither good nor bad – their value can only be defined in the defined context of clearly defined goals." The goal of this evaluation is to assess the hatchery in the context of specific hatchery and fish management goals. In consultation with local, state, and federal stakeholders it is possible that some of the original hatchery goals may change in response to this evaluation.

The study will build on a longterm data collection and analysis effort organized by DWR to understand the hatchery and in-stream ecology of the Feather River system. Following are some of the key reports to be included in this analysis. (Complete citations are in the References section of this report.) Note that italics identify reports in draft stage. Authors and completion dates of the draft reports have not been determined but information in all these reports will be available for use in this analysis.

- Dettman and Kelly. 1987. The roles of the Feather and Nimbus salmon and steelhead hatcheries and natural reproduction in supporting fall Chinook populations in the Sacramento River basin.
- Cramer. 1992. Contribution of Sacramento basin hatcheries to ocean catch and river escapement of fall Chinook salmon.
- Brown and Greene. 1994. Evaluation of the Feather River Hatchery as mitigation for the construction of the State Water Project's Oroville Dam.
- Sommer, McEwan and Brown. 2001 Factors affecting Chinook salmon spawning in the lower Feather River.
- Banks et al. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of Chinook salmon (Oncorhynchus tshwaytscha) in California's Central Valley.
- Hedgecock et al. 2001. Application of population genetics to conservation of Chinook salmon diversity in the Central Valley.
- McEwan. 1999. Feather River study – highlights of salmon emigration studies, 1996-1998.
- DWR 2002 – Emigration of juvenile Chinook salmon in the lower Feather River, 1998-2001
- DWR staff – *Feather River spawning escapement – a history and critique*.
- DWR staff - *Species composition and the effects of environmental variables on fishes of the lower Feather River – 1997-2001*.
- DWR staff - *Redd dewatering and juvenile steelhead and Chinook salmon stranding in the lower Feather River, 2000-2001*.
- Cramer, in preparation. *Estimation of total catch and escapement from fall Chinook salmon produced at the Feather River Hatchery, 1967-2002.* Note that this analysis will be expanded to include spring run and subsequent years. The length of the period of record will depend on the availability of tag recoveries from Central Valley streams and hatcheries. Ocean tag recovery, decoding and posting are complete through the 2001 fishing season.

6.0 Detailed Methodology and Analysis

Completing the following tasks will provide the information necessary to prepare an evaluation of the impacts of the Feather River Hatchery on naturally spawning Central Valley steelhead and Chinook salmon. Tentative

dates for completing each task are included, with the dates built around the assumption that a complete draft report will be due by the end of the first quarter of the 2004 calendar year. Note that the dates mentioned in Timing are for the final reports. DWR and other technical staff will identify a schedule for submitting and reviewing draft sections. Also included are specific references to those areas of concern identified by NMFS.

Task 1. Conduct and document a comprehensive review of the literature regarding the impacts of salmonid hatcheries on naturally spawning salmonid populations.

Rationale: Hatcheries have been used for extensive salmonid propagation for more than 100 years. There have been literally hundreds of laboratory and field studies designed and conducted to evaluate the impacts and benefits of these hatcheries. The proposed literature review will be used to summarize the finding from these studies. The literature review may also provide information leading to additional studies at the Feather River Hatchery.

Timing: An initial draft of the conclusions and citations from the literature review will be available within two months from the time the SP-F9 study plan is approved. Note that the literature review will continue through the end of the report preparation period as new publications become available. The literature review will be the primary task during the first two months after study plan approval.

Task 2. Describe the goals and objectives (1967 through time period of existing license) of the mitigation aspects of the Feather River Hatchery.

Rationale: Completing this task is essential to the hatchery evaluation (Waples 1999) and will involve a review of the original FERC license, the subsequent modification to the FERC license requiring that DWR stock coldwater fishes in Oroville Reservoir and any DWR/DFG agreements about mitigation goals. As appropriate, this review will include agreements about the enhancement aspects of hatchery facilities and operations.

Methods: Completing this task will consist of a review of various agreements, licenses (including FERC), on-going discussions, and information gained from DFG managers.

Timing: To be completed by December 31, 2003.

Task 3. Characterize the non-genetic aspects of the Feather River and other Central Valley salmonid populations and runs.

Rationale: The study involves assessing the impacts of the FRH on naturally spawning salmonids. This study element will be used to describe the non-genetic characteristics of the potentially affected populations.

Methods: Information for this task will be assembled from existing literature and unpublished records. Recent population trends will be taken from the latest edition of the annual report by the Pacific Fisheries Management Council (for example, PFMC 2002). Historical information on distribution will be from Yoshiyama et al. 2001 and references contained therein as well as published and unpublished run history data from the DFG. Some of the information to be compiled includes:

Population trends for all major populations.

Flows and flow agreements for the Feather River

Physical description of the Feather River, including flows, gravel quality and sediment loading.

Spawning distribution and timing in the Feather River and other major streams

Outmigration timing and size at emigration for the Feather River and other major streams.

In-river rearing, in particular for steelhead.

Much of this information will be developed as part of SP-F10 and will be extracted for use in SP-F9.

Timing: The report describing this task will be completed by February 2004, shortly after the escapement data for 2003 are available from DFG and PFMC.

Task 4. Characterize the Central Valley fish management context in which the FRH operates,including other hatcheries, interbasin transfer of genetic material, escapement goals andcommercial and recreational fisheries management.

Rationale: The FRH operates as part of a broad Central Valley and Pacific Ocean fish management process. For example, PFMC fall Chinook escapement goal for the Central Valley is 120,000 to 180,000 spawners. Operations at the FRH can affect attainment of that goal. In addition ocean regulations to protect listed species or weak stocks can affect harvest rates and escapement to the Feather River and other streams.

Methods: Reference materials will be used to describe anadromous salmonid management in the Central Valley. Important sources will be USFWS (2001), NMFS/DFG (2001), PFMC (2002), Busby et al. (1996) DFG (1998) and DWR/USBR (2000) and annual reports from Central Valley hatcheries. This task will focus on spring and fall Chinook and steelhead.

Timing: The report describing the results of this task would be completed by December 31, 2003.

Task 5. Describe FRH facilities and operations for the period 1967-2002.

Rationale: This information is necessary to define the hatchery practices that may have lead to impacts to naturally spawning salmonid populations. For example, the change from on-site releases to releases of production fish in San Pablo Bay.

Methods: The list of information needs has been adapted from the HGMP guidelines (NMFS 1999).

This information shall include, but not limited to:

Water source

Facilities (broodstock collection, broodstock holding, incubation, rearing)

Founding stock – origin and identity

Broodstock selection

Mating protocols

Incubation and rearing

Release information including numbers, sizes and locations

The information will be compiled from annual reports (for example Schlichting 1978) and internal files. The DFG hatchery manager has assigned temporary help to digitize hard copy records.

Timing: The chapter describing FRH practices will be available by December 31, 2003.

Task 6. Characterize the genetic composition of Chinook salmon and steelhead spawning in the Feather River.

Rationale: There are nominal spring and fall Chinook spawning runs to the Feather River and one of the concerns is that, over the past 30 plus years of operation, hatchery practices have resulted in co-mingling spawners and blurring genetic differences between the runs. There are also genetic concerns about steelhead – that is, are Feather River steelhead genetically distinct from other Central Valley steelhead runs? Methods: The procedures for Tasks 5 and 6 are essentially the same and are briefly described below. The procedures are somewhat different for Chinook salmon and steelhead.

Steelhead. Steelhead genetic characterization is being conducted by DFG with funding from CALFED and the USFWS with the following objectives (Modified from personal communication by Katie Perry, DFG):

Describe and compare the genetic profile of Central Valley and coast-wide naturally spawning steelhead populations.

Describe and compare genetic profiles of steelhead populations in specific Central Valley streams.

Describe and compare genetic profiles of Central Valley hatchery steelhead populations and compare with naturally spawning populations.

Analyze the genotype of self-sustaining, putative native Central Valley rainbow trout populations and determine their relationship to anadromous and non-anadromous rainbow trout populations and strains.

Evaluate genetic structure and variation in naturally spawning Central Valley steelhead populations.

Tissue collection began in May of 2001 and is essentially complete. DWR assisted DFG in collecting tissues from the Feather River. More than 1300 samples have been collected (see Table 1, at end of this study plan) and are being forwarded to a USGS laboratory for analysis. Results are expected in early 2003.

Although the DFG study has been developed for a slightly different purpose, the data, and other information, will be used to assess the possibility that FRH operations have adversely affected steelhead in the Feather River and other streams. Particular attention will be paid to founding stock – its source and genetic identification.

Chinook salmon. The following is a brief description of the procedures for examining the genetic composition of Feather River Chinook salmon. For more detailed information see Banks et al. (1999, 2000) and Hedgecock et al (2001).

For various reasons in the mid-1990s DWR became interested in the use of genetic markers to discriminate among the four Central Valley Chinook runs. Through a rigorous RFQ process, DWR selected researchers at UC Davis' Bodega Marine Laboratory to conduct the research. The researchers proposed to use highly polymorphic microsatellite markers (a class of variable number tandem repeat loci) to determine if run discrimination was possible. The research involved several phases:

With the help of agency biologists, the researchers identified significant Chinook salmon populations to be sampled, including all four runs, several streams and Central Valley hatchery stocks.

DWR contracted with the DFG to collect and archive tissue samples from the selected populations. Collection protocols were specified and DWR provided freezers in which the archived samples were to be held. A complete record was maintained of the source and disposition of the archived samples.

Subsamples of the archived samples were periodically delivered to the Bodega Marine Lab for analysis.

UCD researchers either purchased or developed their own microsatellite markers for characterizing the genetic structure of Central Valley salmonids. The scientists developed a software program (Banks and Eichert 1999) to help convert the raw data into run discrimination.

The researchers at Bodega periodically discussed their findings with a panel of other geneticists including Robin Waples (NMFS), Don Campton (USFWS) and Phil Hedrick (University of Arizona).

To ensure credibility, the researchers published their results and conclusions in mainline technical journals.

These procedures were modified slightly during the course of the study to address specific fall/spring Chinook issues on the Feather River. Preliminary results (Figure 2) indicated that the genetic makeup of putative spring Chinook and fall Chinook in the Feather River were identical – and more similar to the Central Valley fall Chinook profile than spring Chinook profiles from Deer, Mill and Butte creeks. Field and hatchery personnel, as well as the fishing community had documented a Chinook run that met traditional spring Chinook characteristics – i.e., early arrival on the spawning grounds, holding for a few months before spawning in the early fall. The researchers addressed the apparent

phenotypic/genotypic anomaly by collecting samples from those fish exhibiting spring run characteristics and by developing an additional suite of markers that might allow differentiation (Hedgecock et al, In prep.)

The work sponsored by DWR will not be only genetic characterization work that has been or is being conducted on Central Valley Chinook salmon. Dr. Bernie May and his colleagues have been working on a CALFED funded project (San Joaquin River Basin Genetic Baseline Study – a study that also analyses tissue samples from the Sacramento basin) with the results expected to be published in December, 2002. The NMFS Santa Cruz laboratory is embarking on a Comprehensive Assessment of Genetic Population Structure and Genetic Diversity for Central Valley Chinook salmon. Other researchers have used mitachondrial DNA (Nielsen et al, 1994) and allozymes to look at divergence among Central Valley Chinook salmon. DWR will contract with a geneticist to prepare a report that describes the information that bears on the question of spring/fall genetic divergence in the Feather River.

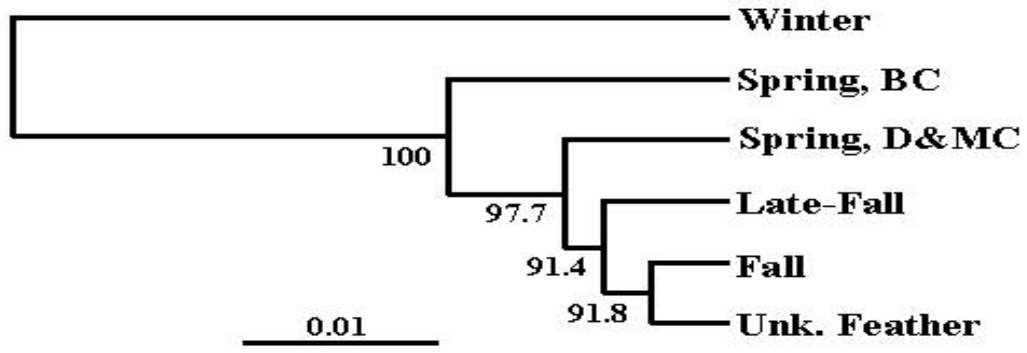

Figure 2. Clustering of Central Valley Chinook samples by similarity at seven microsatellite loci shows Chinook of unknown (spring?) race in the Feather River to be most closely related with fall Chinook. (Hedgecock et al, 2001)

DWR is seeking to determine if another approach to analyzing the genetic composition of both Chinook salmon and steelhead – a search for scales taken from fish during days when hatchery production was minimal, 50s and 60s. If a useable set of scales can be found, DWR will contract with an appropriate laboratory to have them analyzed.

Finally, if it appears that additional samples from salmonids could yield useful information, DWR will work with the regulatory agencies to get permission to collect tissues and with laboratories to get the samples analyzed.

Subtask 1. Continue working with geneticists at UCD, Oregon State University and NMFS to develop information about genetics of Feather River Chinook. Contact DFG biologists to determine if there are archived scale samples from the pre and early hatchery period – that is the 1950s and 1960s.

Subtask 2. Convene a small group of geneticists in early October 2002 to discuss the findings to date, the samples that have been analyzed, the markers used, and to determine if additional analyses are needed. The geneticists will also be asked to evaluate the possible development of a genetics model to assess the impacts of the FRH hatchery on interbreeding between spring and fall Chinook on the Feather River. The results of this meeting will be summarized and made part of the official record.

Subtask 3. Document these findings in a summary report, to be prepared by a geneticist.

Subtask 4. After the summary report from Subtask 3 is available, in the spring of 2003, convene a small workshop of technical experts to discuss the implications of the findings to the Feather River and other streams.

Timing: A complete draft summary of the genetic information for both Chinook salmon and steelhead will be completed by June 30, 2003.

Task 7. Characterize the genetic composition of Chinook salmon and steelhead from Central Valley streams other than the Feather River.

This task is essential to looking at the effects of the FRH on naturally spawning salmonids in other Central Valley streams. The approach, information base, and timing are the same as described in Task 5.

Task 8. Estimate the FRH contribution to the in-river and hatchery spawning population of fall and spring Chinook and steelhead returning to the Feather River

Rationale: In order to evaluate the impacts of the FRH on naturally spawning salmonids, it is important to know how many of the in-river and hatchery spawners are of direct hatchery origin. Stated another way, what is the relative contribution of the hatchery and natural spawning to overall escapement? If the results indicate that by far the majority of the spawners come from the previous natural spawn, the conclusions about impacts would be different if the results indicated that the spawning population consisted almost entirely of direct hatchery returns.

Methods: The primary method to be used in this task involves tagging a fraction of the hatchery Chinook salmon production with binary coded magnetic tags and releasing the tagged fish with the production fish. The tags are recovered (and decoded) from fish collected in the ocean, on the spawning grounds and in the hatchery. The recovery

information will be used in a "cohort analysis" to develop estimates of the absolute numbers, and percentages, of total in-river and hatchery spawners that are of direct hatchery origin.

A secondary method to estimate hatchery contribution to the salmon spawning population from September through December will involve the analysis of sulfur isotopic ratios in the body tissue and otoliths of a randomly selected sample of 200 spawners collected on the spawning grounds. (See Weber and others (2002) for a description and theory supporting the use of this technique.) This proven technique can readily be used to distinguish hatchery from stream-rearing fish because the hatchery ration has a major component from marine sources – sources which have a different sulfur isotopic signature.

For steelhead, analysis of hatchery contribution to the spawning run will be estimated from the fraction of hatchery spawners that have both an adipose fin clip and a magnetic tag is detected in the fish selected for spawning. All Sacramento Valley hatchery steelhead are marked with an adipose fin clip and for a few years, Feather River hatchery steelhead had magnetic coded wire tags.

The following provides a brief description of the mark/recapature protocol used to estimate the fraction of hatchery spawners in the river and the hatchery. Note that this study is expected to continue into the foreseeable future, probably as part of a constant fractional marking program at all Central Valley Chinook salmon hatcheries.

The field and laboratory program to develop this estimate began in 1995 and was an outgrowth of the 1992 analysis by Cramer that indicated conclusions regarding the fraction of hatchery fish returning to the Feather River were limited by the number of tags applied at the hatchery. The resulting FRH tagging program involved both spring and fall Chinook thus tagging can also help determine if the spring and fall populations meet one of the key attributes of a Evolutionary Significant Unit - that is "the population is substantially reproductively isolated from other conspecific population units" (Waples 1995). The tagging studies help in this assessment by providing information about the fidelity of run designation at the hatchery – that is, spring run return as spring run and fall as fall run.

Many of the elements in this task are the same as in Tasks 8, 9 and 10. Differences will be noted as appropriate. The general study plan is as follows.

In the late summer of each year a meeting with the hatchery manager, IEP staff and the tagging contractor was held to allocate the available tagging capacity among production tagging, tagging fish destined for Oroville Reservoir and tags for research in the Delta or other locations in the Central Valley. Each year the attendees also decided on the tag allocation between spring and fall Chinook runs.

The tagging crews usually started in late February with the largest fish available. Because even the larger fish were relatively small, ½ coded wire tags (as compared to full size tags) were often used early. The tagging crews normally worked two shifts and could tag and clip the adipose fin of up to 50,000 fish per day.

Tagged production fish were mixed in with total production for trucking and release in San Pablo Bay.

DWR contracted to have up to 200,000 naturally emigrating juvenile Chinook salmon in the Feather River tagged each year. These fish provided a natural control against which straying of FRH releases can be compared.

Each year 200,000 tagged fingerlings and 100,000 tagged smolts were released in the Feather River below the Thermalito outlet. The purpose of the in-river releases was to:

Evaluate annual changes in the estimated survival to Chipps Island. The survival estimates were developed by the USFWS by expanding the numbers of tagged fish captured in 10, 10-minute daily midwater trawls. The expansion took into account the fraction of the time sampled and the fraction of the cross-section sampled by the trawls. (See Brandes and McClain (2001) for a more complete description of the survival estimating procedures.) Some of the tagged fish were subsequently captured in the ocean fishery and these returns provided an independent survival estimate. Releases of tagged fish were also made in the Sacramento River near Sacramento, thus allowing the ability to assess the relative survival from in-river release locations and Sacramento to Chipps Island and the ocean.

The subsequent capture of in-river releases in Central Valley streams and hatcheries also allows a comparison of straying between on-site and San Pablo Bay release locations.

DWR funds part of DFG's ocean sampling program to help ensure that tags applied at the hatchery were recovered in the ocean commercial and recreational fisheries. The goal of the program is to sample about 20% of the ocean catch and these data are used to estimate ocean harvest. When possible, heads from adipose clipped salmon were taken and shipped to DFG's Healdsburg laboratory where the tags were extracted and read. The tag information was posted on an electronic database maintained by the Pacific States Marine Fisheries Commission.

Beginning around September 1 of each year, field crews on the Feather River begin annual surveys to estimate the numbers of spawners. These surveys run through December in most years. In addition to obtaining data for spawning estimates, the field crews collect the heads of adipose clipped fish and the heads (and accompanying data) are forwarded to the Healdsburg laboratory. DFG conducted the spawning ground surveys until the fall of 2000. In 2000 DWR took over the survey work to provide a better estimate of spawning escapement and to collect a higher fraction of the tags (B.Cavallo, DWR personal communication).

Also beginning around September 1 of each year, the hatchery began collecting broodstock for spawning. The heads of adipose clipped fish are collected and shipped to Healdsburg for tag extraction and decoding.

Tagging and tag recovery allows one to estimate the fraction of spawners in the Feather River that were of hatchery origin. There are many ways to calculate the estimates but the Interagency Ecological Program's Central Valley Salmonid Team concluded that a technique called cohort analysis offered the most promise. The procedure involved in a

cohort analysis is a relatively straightforward expanded accounting of the numbers of fish from each release group that were caught in the ocean fisheries, caught in the inland fisheries, escaped to spawn in the river or were taken into the hatchery. (See Cramer 1992 for a more complete description of the analytical techniques.)

The cohort analysis requires good estimates of the numbers of fish at each stage as well as the sampling effort used to collect the heads for decoding. For example, in the ocean fisheries the assumption is that the samplers see 20% of the fish. The hatcheries also provide good estimates in that all fish entering the hatchery are sampled. Inland harvest and escapement suffer from two problems. First the estimates of harvest and escapement generally have significant but unquantified error bars. Second the sampling effort to recover tags may not be well defined. To overcome these problems, the analyst must often make assumptions about the stream sampling efforts.

Subtask 1. Collect all FRH tag release, tag recovery information, ocean population and harvest, freshwater harvest, escapement and numbers of adults entering FRH into a common electronic database.

Subtask 2. Use the collected data to conduct a cohort analysis for fall Chinook to estimate the fraction of spawners on the Feather River and adults entering the hatchery that are of direct FRH origin.

Subtask 3. Have the draft cohort analysis report reviewed by technical experts. The main function of the review is to assess the validity of some of the assumptions in the analysis.

Subtask 4. Expand the cohort analysis to include spring Chinook.

Subtask 5. Use the database to evaluate time for smolts and fingerlings to travel to Chipps Island, the relative survival of the life stages to Chipps Island, the annual variation in survival from the Feather River to Chipps Island, any differences in survival to Chipps Island between the past few years and the 70s (have things gotten more fish friendly through the Delta) and return of the in-river planted fish to the Feather River.

Subtask 6. In the fall of 2002, improve sampling on the Feather River to ensure that an adequate and known percentage of the tagged fish are recovered on the spawning grounds. A two person crew will be dedicated specifically to coded wire tag sampling in the Feather River. Each week, and in each of the salmon spawning riffles (forty-six total), as many as 25 salmon carcasses will be checked for the presence of coded wire tags. This will provide an excellent representative sample (consisting of roughly 10,000 fish) from all river areas and spanning the entire spawning reach.

Subtask 7. Review the report by Bailey and Munroe (2000) to determine if the information from their analyses (using a different technique) yielded similar results to the cohort analysis.

Subtask 8. In the spring of 2003, the cohort analysis will be repeated using the 2002 data from inland and ocean tag recoveries to calculate the contribution of the hatchery to the ocean fishery, escapement and straying.

Subtask 9. Use the tag recovery data to estimate overall survival of hatchery releases. These estimated survival rates would be compared to literature values and other data as appropriate.

Timing: This task will be completed by August 31, 2003.

Task 9. Estimate the numbers and percentage of Feather River Hatchery Chinook salmon that stray to other Central Valley streams.

Rationale: Although the general assumption is that hatchery practices result in increased straying, information indicates that straying among natural and hatchery salmonid populations is variable and not well understood (see for example, Quinn 1993). Quinn (1993) also found that releasing juvenile salmonids in periods other than their normal emigration period might increase straying. This observation may be important to the analysis of straying of FRH fish, since it appears that most juvenile Chinook salmon leave the Feather River as advanced fry/fingerlings. All production is released as smolts and for years had been released at various stages ranging from pre-smolts to sub-yearlings.

Methods: This task uses the database described in Task 7 to examine the question of the amount of straying experienced by FRH production fish released mostly in San Pablo Bay. The major difference between data collection in tasks 7 and 8 is that tag collection on other streams is by non-DWR crews. Some information indicates that field crews may not be recovering tags in proportion to their occurrence in the spawning population. For example in 2000 on Battle Creek, the DFG field crews collected tags on about 2 percent of the spawners, about 6 percent of the spawners entering the hatchery had tags and and an informal survey of carcasses by USFWS staff found that about 7 percent of the carcasses had tags. Similar results were found in 2001. (K. Niemela, USFWS personal communication) On the Feather River the percentage of tags decreased markedly as the numbers of spawners increased. (B.Cavallo, DWR personal communication) These findings indicate that estimates of hatchery contribution to in-river spawning and straying will be biased low.

Subtask 1. Use the tag recovery database to tabulate numbers of strays from FRH releases that were found on other streams and in other Central Valley hatcheries. Controls will include recoveries from hatchery production released directly into the Feather River (hatchery control) and from recoveries of tags in progeny of salmon spawning naturally in the Feather River (natural vs hatchery control).

Subtask 2. Use cohort analysis to estimate the numbers and percentage of strays to Central Valley streams and hatcheries.

Subtask 3. Compare straying rates of Chinook salmon released from the Coleman National Fish Hatchery (all fall Chinook on-site releases) to off-site releases from the FRH.

Subtask 4. Investigate the use of a straying index as developed by the USFWS in their biological assessment of artificial propagation at the CNFH and LSNFH. (USFWS 2001).

Subtask 5. Review available literature to determine if straying rates noted in this study differ significantly from other results and if observed rates pose serious genetic for naturally spawning salmonids in other streams.

Subtask 6. Continue to work with DFG, USFWS and others to improve tag recovery efficiency, including documentation of sampling effort. In 2002 DWR will provide DFG and a private contractor with seasonal aid assistance to bolster tag recovery and escapement surveys on the American and Yuba rivers. The USFWS will continue to make an informal estimate of the proportion of tagged fish spawning in Battle Creek.

Timing: This task will be completed by August 31, 2003.

Task 10. Estimate the numbers of Chinook salmon from other Central Valley hatcheries that stray into the Feather River and other Central Valley streams.

Rationale: Most Central Valley salmon hatcheries tag a substantial number of their production releases the exception being the Nimbus Hatchery. Although the exact numbers of tags applied annually, CNFH has been tagging roughly 1 million fall and late fall Chinook annually; the FRH roughly 1.5 million total Chinook split between spring and fall; the Mokelumne and Merced hatcheries generally tag all their production. (And even at Nimbus as a result of a CALFED grant several hundred thousand smolts were tagged and marked in 2001 and 2002. The goal of this task is to evaluate the overall level of straying within the Central Valley. It should be noted that tag recoveries to date indicate that there is no straying of Central Valley hatchery fish into the Klamath-Trinity system or vice versa. Tags from the Central Valley have been recovered in the ocean fisheries off Oregon, Washington and British Columbia. The tag recovery database will be examined to determine if tagged FRH salmon are recovered from streams in Oregon, Washington and British Columbia. .

Methods: Completion of this task uses the same tag recovery database as in Tasks 7 and 8.

Subtask 1. From tag database, compile list of tag releases from other Central Valley hatcheries and recovery of these tags in inland waters, including Oregon, Washington and British Columbia.

Subtask 2. Use cohort analysis to estimate the contribution rates of individual hatcheries to escapement in the Feather Rive and other Central Valley streams.

Subtask 3. Use the collected data to determine if there are release patterns (for example, size at release, release location) that seem to affect straying.

Task 11. Estimate the contribution of Feather River, and other Central Valley hatcheries, to the ocean and inland fisheries.

Rationale: In the Pacific Northwest, fish from salmon hatcheries make up an estimated 70-80% of the ocean catch. Similar estimates from California are somewhat lower (Dettman and Kelley 1987 and Cramer 1992) but indicate that the hatchery contribution is significant. Hatchery contribution from the Central Valley is positive in that the catch of hatchery fish helps support the ocean troll and recreational fisheries off California and southern Oregon. The hatchery contribution can have negative impacts in that it may support a fishery that harvests more fish from naturally spawning (and even wild) stocks that is supportable in the long term. Hatchery fish in the ocean also are part of the ocean ecosystem, providing food for some components (for example, marine mammals) and being predators on other components.

Methods: The same database and analytical techniques used in the previous two tasks will be used to complete task 10.

Subtask 1. Use the tag recovery database and the cohort analysis to estimate the contribution of individual Central Valley salmon hatcheries to ocean harvest – both commercial and recreational.

Subtask 2. To the extent possible, use existing information from PFMC and other sources to determine trends in ocean harvest and fraction of harvest supported by Central Valley hatcheries.

Timing: This task will be completed by August 31, 2003.

Task 12. Assess the likelihood of disease transmission from hatchery to naturally spawning fish (releases below hatchery) and to hatchery fish (releases above the hatchery) and the effects of hatchery operation on water temperature in the Feather River

Rationale: Transmission of disease from hatchery to the progeny of naturally spawning salmonids is a potential environmental threat. Disease transmission can occur from released fish or from viable pathogens in the hatchery effluent. Although there is little evidence that hatchery diseases are spread to wild or naturally spawning fish (Waples 1999), information on this topic is rather limited.

Infectious hematopoietic necrosis virus (IHNV) is of particular significance on the Feather River. In the past few years there have been rather severe outbreaks of IHNV in the hatchery and there appears to one or more specific Feather River strains of the virus in the Feather River watershed. (Tresa Veek, DFG, personal communication) and three groups of IHNV in California anadromous salmonids. (Ron Hedrick, UC Davis, personal communication)

Hatchery operation can affect Feather River water temperatures and these temperature changes have the potential to adverse salmonids and other fish inhabiting the stream.

Methods: This task is covered under separate study plans (SP-F2 for disease and SP-W1 for temperature) and is listed here only for completeness.

Because of timing in study plan approval, the following disease related task is included in SP-F9.

Subtask 1. Ron Hedrick of UCD will prepare a draft proposal to conduct additional sampling of hatchery and naturally spawning salmonids in the Feather River and other watersheds to establish baseline of isolate types present in the Central Valley and to assess the hypothesis that hatchery practices are transferring endemic Feather River strains to other salmonid populations. Dr Hedrick will submit the proposal to DWR for consideration. DWR and other agencies will determine if parts or the entire proposal are appropriate for funding through the FERC process or, through other funding possibilities.

Timing: Information from elements F2 and W2 will be used in task 12, as it becomes it available. A decision on subtask 1 of this element is expected to be made in October 2003.

Task 13. Assess the ongoing and future impacts of the FRH on naturally spawning Chinook salmon in Central Valley streams.

Rationale: This is the essence of the evaluation. Hundreds of reports and papers are available on the topic of hatchery impacts. The literature provides numerous examples of where impacts have occurred and been documented. The results of the review must then be used in the context of specific findings about the Feather River Hatchery to assess impacts.

Methods: The assessment will be based on a combination of information collected in the previous tasks, and in particular the literature review. Integration of information from other FERC study elements (for example, F10, F2 and W2) will be essential for completion of this complex task.

Before going to the subtasks, the following is a list of potential hatchery impacts that will be used to guide the assessment. The useful list was developed by NMFS. Note that the list is preliminary and will be added to and modified as we go through the process. Included in the list are a few comments on how the any information collected in this and other studies will be used to evaluate the concern.

***Straying rate*. DWR will augment DFG staff on the American and Yuba rivers in the fall of 2002 to improve the tag recovery and escapement estimates. The data from the augmented surveys will increase the precision and accuracy of calculated straying rates.**

***Effects on run timing*. Hatchery records will be used to determine if run timing has changed over the period of record. Hatchery records will be supplemented by information from SP-F10 on timing of in-river spawning. These data may be augmented by run timing data gathered as the result of keeping the fish ladder open for a longer period namely, April 1 through June 15, 2003. During this period, salmon entering the hatchery would be counted according to a protocol to be submitted by September 30, 2002 to NMFS and CDFG for approval.**

1. *Effects on morphology*. Hatchery records will be used to evaluate any changes in morphology (primarily length and weight) observed over time. Information from the ocean fishery will also be used to determine if changes in weight and size are due to changes in ocean harvest (i.e. taking fish before they have time to reach full maturity as per Ricker 1981) Hatchery records and data from in-river trapping will be used to determine if hatchery fish and naturally spawning juveniles are morphologically different. Another source of information comparing the morphology of hatchery and naturally spawning juvenile Chinook salmon will be from a NFMS study "Smoltification of Chinook salmon from California's Central Valley." Preliminary results indicate some differences in fat content, silvering and bilateral fin symmetry between fish from the FRH and in-river juveniles. (Bruce McFarlane, NMFS, personal communication, 2002). DFG will collect

morphometric data from a random sample of juvenile hatchery steelhead, if possible from a sample of the progeny of steelhead naturally spawning in the Feather River. The choice of measurements and sample size will be left to DFG.

2. *Outbreeding depression*. Although there are theoretical basis for concerns about outbreeding depression, there is little confirmation of the problem in from empirical studies (Campton 1995). The operating assumption in the FRH evaluation is that straying increases adverse impacts due to outbreeding depression. Thus the straying rates estimated in task will be used as a surrogate for outbreeding depression.

3. *Reduced predator avoidance*. Juvenile salmonids reared in captivity are not conditioned to avoid most predators. Information to assess this effect will be from literature reviews and data from Feather River in-stream studies (eg predator abundance, food habits, migration timing). Releasing production fish in San Pablo Bay avoids in-stream predators but does subject the fish to another set of predators such as gulls and striped bass. The use of net pens appears to reduce near term predation and the results of comparing the survival of net pen released fish with that of fish released directly from the transport vehicles will be included in the final report. In addition to a general literature review, DWR will work with USFWS biologists evaluating a more natural rearing environment at CNFH and its affects on smolt and yearling quality (Zydlewski, et al in press.)

4. *Disease transmission to "wild" fish*. Information from F2 will be used to assess this potential adverse impact. See item 12 above for possible additional sampling that may be conducted to obtain more specific information on strains of IHNV that may be found in the Feather River and other Central Valley basins. These data will be used to help assess the likelihood that endemic IHNV Feather River strains are being transmitted to other population of Central Valley salmonids. DWR has received a proposal from Dr. Hedrick of UCD to perform additional disease related studies on Central Valley salmon. DWR is reviewing the proposal and is particularly interested in those components related directly to Feather River Chinook.

5. *Selection for non-territorial behavior in pre-smolts*. Since, in recent years all FRH production has been released as smolts in San Pablo Bay, this is not an issue. The literature will be examined to determine the extent of the problem as background for a possible change in hatchery practices.

6. *Selection for reduced activity in pre-smolts*. Same comments as for number 6.

7. *Early maturation in smolts.* The hatchery data assembled as part of Task will be used to assess this potential problem. Preliminary information (Tresa Veek, DFG, personal communication) indicates that there is no indication of early sexual maturity in Chinook smolts scheduled for release as production fish. In the winter of 2002/2003 DFG pathologists will sacrifice 200 randomly selected yearling

steelhead to assess their condition, including maturation of testes and any apparent abnormalities.

8. *Increased numbers of two-year olds (jacks) in the spawning population*. Hatchery data collected in Task will be used to assess the percentages of jacks entering the hatchery and if the percentages have changed over time. These data will be compared to streams with and without hatcheries to determine if any trends are unique to the FRH.

9. *Return of runs to hatchery as opposed to appropriate habitat*. See comment below on superimposition of redds.

10. *Hybridization between runs*. This genetic information will be available from Task 6. A meeting of geneticists will be convened in October 2002 to examine the available data, the samples analyzed and additional samples available for analysis. The geneticists will determine if additional samples would shed additional light on the conclusions regarding hybridization.

11. *Unintentional mating of behaviorally/physically deficient fish* – inbreeding depression. This concern can be rephrased as loss of fitness of hatchery populations and is one of the core concerns in this evaluation. The concern is also difficult to address. In this evaluation the following information will be used to address the issue.
    - Use survival to Chipps Island data, survival to the ocean fishery and overall cohort survival (all from the tag recovery database as surrogates for fitness of FRH fish. These data will be compared with information from the in-river tagging program survival rates (progeny from natural spawners) and other hatcheries and systems to evaluate the fitness of FRH production fish.
    - Use information from USFWS/IEP studies of Delta survival to compare fitness of FRH fish as compared to fish from other facilities including the CNFH and the Merced Fish Facility.
    - Use information from the American River comparing the fitness of hatchery and progeny of naturally spawned fish – with fitness measured as swimming ability (Joe Cech, UC Davis, personal communication, 2002.)

    DWR will evaluate the use of a genetic model to address this issue.

12. *Superimposition of hatchery redds on wild redds*. Questions regarding the spatial and temporal distribution of hatchery salmon, and the extent of superimposition among salmon redds will be addressed by studies described in Task 2B of SP10, Chinook Salmon Carcass Survey. Carcass survey data will include the number of fish spawning in each distinct spawning riffle on the Feather River. The CWT collection component of the carcass survey will also provide a weekly estimate of CWT rates for each of the spawning riffles. The rate at which CWT salmon carcasses are encountered can then be used as an index of hatchery fish abundance. Analysis of CWT rates relative to river location, habitat quality and number of

salmon will provide information about the habitat selection and tendencies for superimposition among hatchery salmon.

If the literature review and assessment of data from Feather River instream flow studies indicates that reduced predator avoidance is a potential problem for juvenile salmonids reared in the FRH, the Environmental Work Group will immediately develop a study plan to evaluate the susceptibility of FRH salmonids to predation relative to predation of wild juvenile salmonids. The Environmental Work Group should consider an experimental study of juvenile salmonid avoidance in a laboratory setting or releases of experimental juvenile salmonid groups in the Feather River, which would be given predator challenges similar to those currently being applied at other facilities. If the Environmental Work Group determines that the latter study should be undertaken, the timing of the study would be adjusted to coincide with the timing of other protection, mtigation and enhancement (PM&E) studies because the results of such studies would not be available until the released fish return as adults which is after the filing of the license application. Additionally, if FRH juvenile salmonids demonstrate reduced predator avoidance and the Environmental Work Group determines that a goal of the FRH is to improve predator avoidance, the Environmental Work Group will consider a study aimed at training hatchery smolts to avoid predators upon release. Such a study could also be considered for inclusion into the settlement agreement.

If non-territorial behavior in pre-smolts.or reduced activity in pre-smolts are determined to be a potential problem, the Environmental Work Group will consider conducting experimental studies aimed at meeting identified goals of the FRH.

Subtask 1. Organize a technical review committee to assist in reviewing the products of this evaluation. This review committee could include members of the current technical input group augmented by one or two specialists. Much of the material to developed will be highly technical and not in the realm of technical expertise of most of the participants. A representative from the CNFH would be an important member of the technical review team.

Subtask 2. Summarize the results of USFWS and NMFS studies that used FRH fish in various field studies. In many of these studies the investigators obtained physiological or morphological data on the test animals and in some studies evaluated the relative through-Delta survival of smolts from more than one hatchery.

Subtask 3. Arrange for periodic joint meetings with the DFG/NMFS hatchery task force to ensure that we are working towards mutual objectives.

Timing: Of necessity this will be one of the last tasks completed with an expected completion date of December 31, 2003.

Task 14. Evaluate the effects of FRH steelhead planted in the Feather River on naturally spawning steelhead in the Feather River.

Rationale: The significant differences in the biology and life history of Chinook salmon and steelhead dictate that many aspects of the steelhead evaluation be handled in a separate task.

Methods: Many of the methods have been outlined in F10. Completing this task will require coordination between F10 and integration of the results of these two components in the final synthesis report.

Subtask 1. Review applicable literature on the effects of steelhead conservation and production hatcheries. This subtask task will be completed as part of Task 1, the overall literature review.

Subtask 2. Summarize hatchery spawning and production for the period of record.

Subtask 3. Compile and assemble information collected in the Feather River pertaining to rearing and outmigration of juvenile steelhead. These data will include habitat use, food habits, catches of steelhead in rotary screw traps and other sampling methods.

Subtask 4. Examine tag return data to determine if they are adequate to describe the movement of FRH juvenile steelhead.

Subtask 5. Summarize information from DFG's recreational angler surveys to estimate harvest rate on hatchery steelhead.

Subtask 6. Examine catch and distribution data to determine the extent of straying of FRH steelhead into the Yuba River and other Central Valley streams.

Timing: The information needed to complete this task will be assembled by December 31, 2003 with a draft chapter describing the effects of the FRH on steelhead to be completed by March 31, 2003.

Task 15. Construct conceptual models of the role, and impacts of the FRH operations on naturally spawning salmonids.

Rationale: Conceptual models provide a useful and informative means of describing our understanding of the system. Including conceptual models as a specific task will make the assumptions and conclusions explicit.

Methods: The basic approach will be to prepare a combination of narrative and box and arrow conceptual models and provide them for discussion and review. The models will

be revised as new information becomes available. It is expected that the models will be "living documents" that will assist in the continued evaluation of the FRH.

The following is a very brief example of a conceptual model – a model that will be expanded as a result of this investigation.

- The FRH rears Chinook salmon to mitigate for the loss of salmonid spawning and rearing habitat lost when Oroville Dam was constructed.
- Survival of juveniles planted in San Pablo Bay is higher than juveniles planted on site.
- Releases of production Chinook salmon in San Pablo has resulted in straying to other streams and possible interbreeding of wild and hatchery fish.
- This interbreeding can depress the fitness of wild Chinook.
- Straying rates can serve as surrogates for population impacts.
- .Hatchery practices that select for certain traits (time of arrival at the hatchery, size, fecundity, etc.) as well as the general hatchery rearing conditions (feeding methods and diseases) may reduce the overall fitness of Chinook salmon and this reduced fitness may be transferred from generation to generation.
- In the past few years a combination of a successful hatchery, a new in-Bay release strategy (use of net pens), reduced ocean harvest, good ocean conditions, and spawners being drawn to the river channel immediately below the barrier dam has resulted in spawning runs that exceed the available spawning area. The large number of spawners competing for a relatively small area results in redd superimposition and may be affecting productivity of natural spawners.
- Central Valley Chinook salmon, including those in the Feather River, suffer from a variety of diseases. The occurrence and intensity of disease outbreaks can be intensified by intensive culture practices used in hatcheries and the diseases, in turn, may affect natural populations.

Subtask 1. Develop a preliminary narrative conceptual model of Chinook salmon life history in the Feather River as affected by operations of the FRH.

Subtask 2. Develop a preliminary narrative conceptual model of the steelhead life history in the Feather River as affected by operations of the FRH.

Timing: Complete initial draft conceptual models by December 31, 2003 and circulate for review. Complete second draft of model section by March 31, 2003.

Task 16. Assess the contribution of the FRH to public education and outreach.

Rationale: The FRH provides an important source of public education and outreach to the community and local area.

Methods: Use existing records to summarize the such outreach events as the number of field trips schools make to the hatchery each year, attendance and agenda for the annual salmon festivals and school science projects.

Timing: Complete this task by September 30, 2003.

Task 17. Assess the economic contribution of the FRH to the California economy.

Rationale: The FRH contributes to ocean and inland harvests and these harvests have economic benefits. The hatchery also contributes to the local economy.

Methods: Data will be collected on ocean and inland harvests and standard economic models will be used assess the benefits to the California economy. Hatchery costs will be quantified to calculate a cost: benefit ratio.

Timing: This task will be completed by November 30, 2003.

Task 18. Develop information to be used in identifying and assessing the feasibility of potential new protection, mitigation and enhancement measures.

Rationale: A preliminary review of the literature clearly demonstrates that operation of typical salmonid hatcheries can adversely affect naturally spawning salmonid populations. Completion of this evaluation will likely confirm that the FRH has had adverse impacts, as well as benefits. The ultimate goal of the evaluation is to modify hatchery operations to reduce the risks to naturally spawning populations. These modifications should be in the context of the entire Central Valley hatchery/salmon management system.

Methods: Information to complete this task will come from the previous tasks as well as from other salmonid hatcheries facing the same risk minimization/fulfilling mitigation responsibilities challenge – for example the Coleman National Fish Hatchery.

Some special studies may be implemented to provide additional information. These studies could be tied to the following potential modifications to the hatchery or hatchery practices.

- Changing the timing of spring run broodstock selection to the first few days in September, as originally practiced by hatchery managers. The special studies could involve:
    - As proposed by DWR (Brad Cavallo, DWR, personal communication, 2002), keeping the gates to the fish ladder open through June 15 to better determine run timing, maturation, sex ratios, genetic composition and fraction of hatchery fish of those nominal spring Chinook arriving on the Feather River in late spring. DWR proposes to begin this study in the spring of 2003. The

study would also provide useful information on adult steelhead in the Feather River.
    - Obtain information similar to the above for those nominal spring Chinook that enter the hatchery before September 5.
- Tagging all spring run production. This was recommended by the DFG/NMFS (2001) report. An alternative strategy is to tag 2 million nominal spring run juveniles. The alternative strategy is being recommended by DWR for the 3-year period beginning in the spring of 2003.
- Releasing spring run production in the river. This strategy was recommended in the DFG/NMFS report. An alternative strategy, as recommended by DWR, is to tag and release about 1 million spring Chinook smolts into the Feather River and another 1 million as part of the production releases into San Pablo Bay. This strategy would be implemented in the spring of 2003 and continue for 3 years.
- Find physical means of separating spring from fall spawners in the Feather River.
- Evaluate the net pen release strategy being used to reduce near term mortality of smolts released into San Pablo Bay. Included in this evaluation would be the interaction between increased survival, ocean harvest, and escapement to the Feather River and straying to other Central Valley streams.

Subtask 1. Organize a meeting of interested biologists to discuss spring Chinook on the Feather River and potential release and tagging strategies. (Note that this meeting occurred on June 6, 2003.)

Subtask 2. Develop a study plan to evaluate the in-river and other effects of releasing three groups of tagged spring Chinook smolts into the Feather River and follow their migration and survival to Chipps Island. This release would be the first part of an adaptive management experiment to assess the benefits and effects on in-river releases. The study plan would include a comparison of the relative benefits of on-site versus off-site releases in terms of straying, competition, predation and disease transmission.

Task 19. Prepare final report synthesizing the information from the above tasks in combination with information from other elements of the Oroville Project evaluation.

All the information related to this study plan will be compiled into a narrative report, with the report organized along the general format of a Hatchery Genetics Management Plan. Using this approach presents the information in a format readily used by DFG and NMFS in preparing the HGMP for the FRH. Specific FERC-related study elements that will provide information for the final hatchery evaluation report are:

- SP-W1. Project Effects on Water Quality Designated Beneficial Uses for Surface Waters, specifically with regard to the effects of hatchery produced fish on nutrients and dissolved oxygen in the river.

- SP-W6. Project Effect on Water Temperatures, specifically the effects of the hatchery operation on stream temperature.
- SP-F10. Evaluation of Project Effects on Anadromous Salmonids and their Habitat
- SP-F2. Effects of Project Operations on Fish Diseases

7.0 Results and Products/Deliverables

The information compiled in the above tasks will be assembled into a series of task specific reports. Where possible and informative, data will be organized and analyzed and presented in a series of figures and tables – the tables and figures forming the basis of many of the tasks reports. The ultimate deliverable will be the synthesis report that evaluates the overall effects of the hatchery on naturally spawning salmonids. The synthesis report will based on a combination of data directly related to the FRH and information gleaned from similar analyses of the effects of other hatcheries.

Review will be a key element of the reporting process. The authors of the task reports will submit drafts to appropriate technical and policy reviewers. Any comment will be addressed before the reports are made final.

8.0 Study Plan Coordination

Coordination With Other Resource Areas/Studies. Coordination with other FERC relicensing studies, including those addressing fish disease (SP-F2), salmonids in the Feather River (SP-F10), water quality (SP-W1 & SP-W6), and interbreeding of salmon stocks.

Evaluate the Likelihood Transmission of Disease from Hatchery to Wild Fish

- SP-F2 – Effects of Project Operations on Fish Diseases:

SP-F2 will provide information crucial to the evaluation of stocking practices and artificial production as it pertains to management of fish resources at Oroville facilities.

Many bacteria, virus and protozoa are known to cause various diseases to both wild and hatchery Pacific salmonids (e.g., the bacterium *Renibacterium salmoninarium* that cause bacterial kidney disease (BKD), the rhabdovirus causing infectious hematopoietic necrosis (IHN), the myxosporean parasite *Ceratomyxa shasta* that is lethal to most strains of rainbow trout). It is a current concern to catalogue and assess the incidence of diseases at FRH and evaluate the probability of spreading them to wild fish populations. Activities included in this task are detailed below.

- Review report by Scott Foote 2000 on similar concern about release of Chinook from the Coleman National Fish Hatchery (CNFH);

- Review incidence of diseases at the FRH and CNFH to determine their similarities and if the conclusions from the Foote report can be applied to the Feather River; and
- Work with DWR's fish disease consultant to synthesize data.

Evaluate the Effect of Hatchery Produced Fish on Naturally Spawned Salmonids

- SP-F10 Evaluation of Project Effects on Anadromous Salmonids and their Habitat

Evaluate the Effects of the FRH on Water Quality in the Feather River

- SP-W1 Project Effects on Water Quality Designated Beneficial Uses for Surface Waters

Review the existing and newly acquired data to estimate the water quality effects of the decomposition of spawned salmon of hatchery origin that have returned to the Feather River.

Evaluate the Effect of Hatchery on Water Temperatures

- SP-W6 Project Effect on Water Temperatures

Issues, Concerns, Comments, Tracking and or Regulatory Compliance Requirements

This study would address the project-related effects of the Feather River Hatchery on naturally spawning salmonids. The following specific issues will be addressed: (The list identifies if the issues are directly or indirectly addressed in the study plan. Some of the more complex issues are in both categories. The underlined sentence or clause is the one that is best identified with each category).

Stakeholder Issues Fully Addressed by this Study Plan

Issue	Description
FE31	Several fish hatchery issues need resolution, such as the relationship between the hatchery and restoration of a natural ecosystem, straying and genetic impacts, harvest rates, and disease;
FE87	Introgression occurring between various runs of Chinook salmon and between hatchery and wild salmon and steelhead. This includes direct, indirect and cumulative impacts from hatchery practices, project facilities and operations, lack of adequate spawning habitat and impassable migration barriers that exclude access to historic spawning habitats;
FE88	Impact of hatchery facilities and/or operations on anadromous salmonids. This includes the direct, indirect and cumulative impacts of hatchery product on anadromous salmonids and the direct, indirect and cumulative impacts of hatchery facilities and operations on salmonids and their habitats;
FE93	Introgression occurring between fall-run and spring-run Chinook populations in the Feather River due to hatchery practices and impassable migration barriers;
FE99	The Feather River Hatchery was constructed to mitigate for losses of upstream habitat when the Oroville facilities were constructed. There is a body of evidence suggesting that improperly planned hatchery practices can adversely impact native and non-native

	species including anadromous species. The effects of hatchery practices on naturally reproducing/self-sustaining anadromous populations should be examined as part of the fishery investigations. These evaluations should examine alternative practices that would lead to increased naturally reproducing/self-sustaining anadromous populations. Improper hatchery practices can also lead to transmission of serious fish diseases, and impact overall susceptibility of naturally reproducing populations to diseases.
W13	Effects of existing and future hatchery operations on water quality and water temperatures in the Feather River and Afterbay;
WE33	Relationship between hatchery and water quality.

Stakeholder Issues Partially Addressed by this Study Plan

Issue	Description
FE95	The lower Feather River provides habitat to support a variety of anadromous fish species including Chinook salmon, steelhead, striped bass, American shad and sturgeon. Potential changes in license conditions could adversely impact habitat supporting these species. Habitat investigations should evaluate the existing quality and quantity of habitat and determine alternative improvements for the various life history needs of anadromous species including flow, water temperature, instream and riparian cover, substrate and spatial area;
FE87	Introgression occurring between various runs of Chinook salmon and between hatchery and wild salmon and steelhead. This includes direct, indirect and cumulative impacts from hatchery practices, project facilities and operations, lack of adequate spawning habitat and impassable migration barriers that exclude access to historic spawning habitats;
FE96	The lower Feather River provides habitat to support a variety of resident native and resident introduced species including coldwater species such as rainbow, brook, and brown trout, and warm water species such as bass, catfish, bluegill, green sunfish, carp and others. Potential changes in license conditions could adversely impact habitat supporting these species or upset habitat conditions such that less desirable species are favored. Habitat investigations should evaluate the existing quality and quantity of habitat and determine alternative improvements for the various life history needs of these resident native and non-native species including flow, water temperature, instream and riparian cover, substrate and spatial area;

9.0 Study Schedule

The synthesis report will be completed by June 30, 2004. Individual tasks will be completed in time to meet the final report schedule but in most all cases, the task reports should be completed by March 1, 2003 to allow incorporation in the final report and sufficient opportunity for review. For some discrete components of the individual tasks, the deadlines are:

- Initial results of cohort analysis to estimate contribution and straying rates – June 1, 2002

- Results of increased sampling for tags on the Feather River and Mill, Deer and Butte creeks – March 1, 2003
- Second cohort analysis using additional tag recovery data – April 30, 2003.
- Literature reviews – December 31, 2002. Part of all tasks.
- Complete final report – July 1, 2004

10.0 References

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Table 1 – Samples collected by DFG and others for genetic analysis as part of comprehensive examination of steelhead genetics in the Central Valley.

Sampling Site	
	Number of Samples Collected
Sacramento River, below Keswick dam	75
Cottonwood Creek, headwater region	36

Mill Creek	42
Deer Creek	40
Stony Creek, headwater region	76
Putah Creek, above Lake Berryessa	123
Feather River	55
Feather River hatchery	55
Lower Yuba River	35
Upper Yuba River	116
Lower American River	60
M. F. American River	55
Nimbus Fish Hatchery	51
Calaveras River, below New Hogan Dam	92
Lower Stanislaus River, below Godwin Dam	57
Upper Stanislaus River, below Bearsley Dam	59
Lower Tuolumne River, below La Grange Dam	80
Upper Tuolumne River, between Don Pedro and Yosemite	136
Kings River, headwater region	

Alternate Sites	
Antelope Creek	51
Lower Merced	2
Upper Merced	37

*Note that samples are still being prepared for shipment to USGS